MASTER

ATL-A-117

EURAEK -64

UNITED STATES-EURATOM JOINT RESEARCH
AND DEVELOPMENT PROGRAM

Development of Clad Ceramic Fuel Plates by Spray-coating
Techniques
Quarterly Report No. 1
Advanced Technology Laboratories (A division of American
Standard)
1961

LEGAL NOTICE

This document was prepared under the sponsorship of the United States Atomic Energy Commission pursuant to the Joint Research and Development Program established by the Agreement for Cooperation signed November 8, 1958 between the Government of the United States of America and the European Atomic Energy Community (Euratom). Neither the United States, the U. S. Atomic Energy Commission, the European Atomic Energy Community, the Euratom Commission, nor any person acting on behalf of either Commission:

- A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this document, or that the use of any information, apparatus, method, or process disclosed in this document may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method or process disclosed in this document.

As used in the above, "person acting on behalf of either Commission" includes any employee or contractor of either Commission or employee of such contractor to the extent that such employee or contractor or employee of such contractor prepares, handles, disseminates, or provides access to, any information pursuant to his employment or contract with either Commission or his employment with such contractor.

Facsimile Price \$ _____

Microfilm Price \$ _____

Available from the
Office of Technical Services
Department of Commerce
Washington 25, D. C.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

MASTER

ATL

ATL-A-117

INFORMAL AEC RESEARCH
AND DEVELOPMENT REPORT
UC-25, Metallurgy and Ceramics
SPECIAL DISTRIBUTION

Quarterly Technical Progress Report
DEVELOPMENT OF CLAD CERAMIC FUEL PLATES
BY SPRAY-COATING TECHNIQUES

ATL Job 4010

January-March 1961

for
The U. S. Atomic Energy Commission
Contract AT(04-3)-250
Project Agreement No. 4

UNITED STATES-EURATOM JOINT RESEARCH
AND DEVELOPMENT PROGRAM

EURAE-64

ADVANCED TECHNOLOGY LABORATORIES
A Division of American-Standard
369 Whisman Road
Mountain View, California

601 001

ADVANCED *Technology* LABORATORIES
A DIVISION OF AMERICAN-Standard

STATEMENT OF PROBLEM

The over-all objective of this program is to develop plate-type uranium dioxide fuel elements using plasma-jet-spraying techniques and to evaluate properties and potential cost savings of these fuel elements.

Phase I, currently in progress, is concerned with the development of plasma-jet spray-coating techniques suitable for producing clad ceramic fuel plates. Investigation of spray-coating variables and evaluation of coating characteristics are included in this portion of the program.

SUMMARY OF PROGRESS TO DATE

Calcium-stabilized zirconia was sprayed initially to determine the effects of plasma-spray process variables on such coating characteristics as density and adherence to the substrate. Efficiency and rate of deposition also were studied. The plasma-spray equipment was modified to overcome initial shortcomings, especially with respect to the powder feed system. Under the conditions used in this program, zirconia coatings of 85% theoretical density and 300-psi tensile adherence were deposited with 50% efficiency. This portion of the program is now complete.

Operating conditions for producing UO_2 coatings of maximum density and deposition efficiency have been studied exhaustively, and the effect of all major variables is now known to a considerable extent. Uranium dioxide coatings of 87% theoretical density and O/U ratios of nearly 2.00 have been deposited regularly with efficiencies of about 40%. Maximum densities of 90% and efficiencies of 50% have been obtained. Currently, improved substrate-preparation methods are being investigated, and stress patterns developed in coated specimens as a function of thermal history during and after deposition are being determined experimentally.

PROGRESS JANUARY-MARCH 1961

A. Establishment of Spraying Conditions for Uranium Dioxide

Conditions for spraying fused UO_2 powder were rapidly established by depositing cones on stationary substrates. The heights of the cones were measured and plotted against the variable under study, i. e., powder size, power input, arc-gas flow rate,

powder feed rate, and powder-gas flow rate. Increasing power input and powder feed rate increased the deposition rate as expected, while powder-gas flow rates had little effect. Arc-gas flow rate had a marked effect on cone deposition, as shown in Figure 1 for -200, +325 mesh powder and in Figure 2 for de-slimed -325 mesh powder. Thus, it was found that the arc-gas flow range within which deposition occurs is very narrow. Higher gas flows were required to obtain optimum deposition of -325 mesh powder. Comparison of Figures 1 and 2 indicates that the sub-sieve powders do not deposit as well as does the coarser -200, +325 mesh material.

B. Density of Uranium Dioxide Coatings

Coatings were made from -200, +325; -270, +325; and de-slimed -325 mesh fused UO_2 powders. Table I summarizes the data obtained, and Figure 3 illustrates effect of arc-gas flow rate on the density of coatings made from various powder sizes. The optimum arc-gas flow rate for the -200, +325 mesh material was found to be about 1.25 cfm; insufficient data are available for the other powder sizes studied to date. Smaller powder sizes were found to require higher arc-gas flow rates to achieve densities equivalent to those found for the -200, +325 mesh powder. The -200, +325 and -270, +325 powders were sprayed at varying arc-gas flow rates and nearly constant plasma enthalpies. Therefore, the two curves in Figure 3 represent coating density as a function of arc-gas velocity, and thus particle velocity. An optimum combination, then, exists between the time the particles dwell in the plasma and the velocity with which the particles are transported to and impact the substrate. Below the optimum flow, the particles have more time to cool prior to impact and impact velocities are low. Above the optimum value, dwell time in the plasma is insufficient for good particle melting. Similar effects were noted for ZrO_2 coatings.¹

C. Deposition Efficiency of Uranium Dioxide

To provide data regarding the economics of the process, deposition rates and efficiencies were determined under various conditions. Before this phase of the investigation was initiated, minor modifications were made in the powder feed system to position the

1. Progress Report dated 21 November 1960 (ATL-458).

spray pattern properly in the plasma flame. A completely satisfactory pattern was not achieved because of the powder gas velocities required to effectively carry the dense UO_2 to the plasma jet and because of breakup of the powder in the feed system. Powder screened to assure that more than 95% of the particles were within the range -200, +325 mesh contained about 25% -325 mesh powder as fed to the torch. Fused UO_2 is easily broken into finer particles, and feeding a wide range of powder sizes into the plasma results in a distorted spray pattern. The effects of the variables on deposition efficiency are discussed in the following paragraphs.

1. Powder Size

Three ranges of UO_2 powder sizes were evaluated to determine the influence of particle size on deposition efficiency. The ranges were -200, +325 mesh (-74, +44 μ), -270, +325 mesh (-53, +44 μ), and de-slimed -325 mesh (-44 μ). Figure 4 summarizes the data obtained. It is obvious that the -200, +325 and -270, +325 mesh powders deposit with comparable efficiencies, while lower efficiencies result when -325 mesh powder is sprayed. When -325 mesh powder is sprayed, the chamber atmosphere becomes extremely "foggy" due to a suspension of fine particles. These particles may be undeposited powder or vaporized UO_2 condensing in the atmosphere. It is highly possible that the small particles of UO_2 vaporize when passing through the plasma jet. Improvements in deposition efficiency were noted when the spraying distance was decreased from 4 to 3 inches. Fine powders must be sprayed at a closer distance, since the particles have low mass and lose heat rapidly after leaving the plasma.

2. Power Input

Deposition efficiency is markedly affected by changes in electrical-power input. As the power was increased from 15 to 22 kw, deposition efficiency increased from 15 to 45% (Figure 5). Higher power levels are required to obtain deposition efficiencies equivalent to those found for ZrO_2 .²

2. Progress Report dated 15 August 1960 (ATL-373).

3. Arc-Gas Flow Rate

The flow of argon through the torch has a significant effect on the deposition efficiency, as illustrated in Figure 6 for -200, +325 mesh powder. Highest deposition efficiencies were noted at 1.0 cfm of argon at the power levels, powder feed rates, and powder-gas flow rates studied. Unsatisfactory spray patterns prevail at flow rates below 0.6 cfm, which marks the lower limit at which studies were made.

4. Spray Distance

Distance from the plasma-spray torch to the substrate surface has a pronounced effect on deposition efficiency. With present equipment and spraying conditions, UO_2 cannot be deposited from distances over 4 inches. As shown in Figure 7, deposition efficiency decreased from about 40% at 4 inches to about 1% at 5 inches. Decreasing the distance below 4 inches had little effect on deposition. UO_2 particles cool much more rapidly than do ZrO_2 particles, because of differences in thermal properties. Closer spray distances must be used when spraying UO_2 in order for the particles to retain enough heat to weld together and form a coating.

5. Traverse Rate

Coatings were sprayed at traverse rates varying from 24 to 70 ipm. Coatings made at 24 ipm were deposited at slightly higher efficiencies than those at 50 and 70 ipm.

6. Powder Feed Rate

Powder was added to the carrier-gas stream at rates varying between 16 and 60 gm/min. Data indicate that the best combination of deposition rate and efficiency was obtained at a feed rate of 30 gm/min. The trends and results were comparable to those previously reported for ZrO_2 .²

7. Powder-Gas Flow Rate

It has been found that certain minimum powder-gas flow rates are required to carry the powder from the feed hopper to the plasma torch. Excessive flow produces a poor spray pattern and results in lowered deposition efficiency, as shown in Curve A of Figure 8. As the powder feed rate was increased, higher powder-gas flow rates were required to adequately feed the powder (Curve B).

8. Cover-Gas Flow Rate

A flow of cover gas is used to aid in cooling the surface of the coating and thus to prevent lifting of the coating during spraying. Argon jets were directed at the coating surface from a perforated ring surrounding the plasma and positioned about $1\frac{1}{2}$ inches from the coating surface. A flow of cover gas did not reduce deposition efficiency until the flow was increased above 8 cfm. Cover gas allowed spraying at close distances without cracking, lifting, or spalling of the coatings.

D. Stoichiometry of Plasma-Sprayed Uranium Dioxide Coatings

Oxygen-to-uranium ratios of coatings made for evaluation of density were determined by gravimetric and volumetric methods. Some of the results obtained are tabulated below, where the effect of the spraying atmosphere is illustrated. Volumetric analyses carried out during March indicated ratios of 2.009 to 2.075 for a number of coatings made in a good argon atmosphere.

Oxygen-to-Uranium Ratio of As-Received Powder and Coatings Sprayed under Various Atmospheres (Gravimetric Method)

Spraying conditions: Power Input, 25 kw
Spray Distance, 4 to 6 inches
Arc-Gas Flow Rate (Argon), 1.25 cfm
Powder Feed Rate, 60 gm/min

<u>Spraying Atmosphere</u>	<u>Color of Coating</u>	<u>O/U Ratio Determination</u>
As-Received Powder	Dark brown with reddish brown fines	1.95
Argon, double purge	Light brown	1.93, 1.98
Argon, slight leak in chamber, slight contamination of atmosphere	Light-green tint	2.05, 2.08
Air	Light green	2.34, 2.41

E. Preparation of Thin Substrates (0.030-inch maximum thickness)

One of the problems involved in preparing thin substrates for plasma spraying is the preparation of the surface without distortion. Investigations have commenced for three techniques: 1) sandblasting followed by a straightening operation, 2) chemically etched grid patterns, and 3) light sandblasting followed by etching to produce a clean metal surface.

A program to determine the effect of sandblasting variables on the deformation of thin substrates was completed. Deformation was independent of 1) blasting media, 2) media size, 3) blasting distance, 4) angle of blasting, and 5) substrate condition (annealed or cold-worked). Air pressure, type of blasting equipment, and method of fixturing the substrate greatly influenced deformation. When surface roughness was also considered, the following conditions were best for sandblasting.

Type of blasting equipment:	Suction	Pressure
Blast pressure:	100 psi	25 psi
Fixturing:	Clamp on steel backup	Clamp on steel backup
Type and size of grit:	Silicon carbide, 16 mesh	Silicon carbide, 16 mesh

In attempts to straighten the deformed substrates, it was found that rolling the substrate sheets with a 1/16-inch-thick layer of rubber between the rolls and the sandblasted surface removed most of the deformation.

Chemically etched grid patterns were produced on stainless steel and Zircaloy-2, using the Kodak Photo-Etch Process. The substrate is coated with Kodak Metal Etch Resist and exposed in contact with a negative of the grid pattern desired. Exposed plates are then developed, baked, and etched. Etchants found to be acceptable were 25% HNO_3 , 40% H_2O , 35% HF for Zircaloy-2 and aqua regia for 304 stainless steel.

Chemical reaction between the substrate (such as Zircaloy-2) and the UO_2 sprayed on the surface was investigated. It is not expected that surface reactions alone will provide adequate adherence. However, reactions may enhance adherence when used in conjunction with a roughened surface. Data obtained to date indicate some enhancement of adherence when UO_2 coatings are sprayed on clean, sandblasted Zircaloy surfaces.

F. Determination of Thermal Stresses

Fixturing and instrumentation methods have been designed for measuring substrate and coating temperatures during spraying of typical fuel-element-cladding thicknesses of stainless steel and Zircaloy-2. The amount of curvature found in sprayed composites is measured and correlated with thermal history during and after spraying. Initial specimens have been sprayed and are currently being evaluated.

CONCLUSIONS

Uranium dioxide coatings of 87% theoretical density and O/U ratios very near to 2.00 can be deposited at efficiencies of about 40%. To date, the best coatings have been produced using -200, +325 mesh fused UO_2 powder. Preparing substrates in fuel-element-cladding thicknesses for plasma spraying is a major problem, but techniques such as chemical milling offer promise.

PLANS FOR FUTURE WORK

The program will be directed toward improved adherence to the substrate and fabrication of simulated fuel elements. The following tasks are contemplated for the next quarter.

1. Determination of stress patterns in sprayed composites under various conditions.
2. Development of satisfactory substrate surface-preparation techniques for thin substrates.
3. Design and fabrication of simulated plate-type fuel elements.
4. Preliminary economic analysis of the process for fuel-element manufacture.
5. Completion and distribution of interim report on the results of the study of process variables, including initial results for UO_2 .

PRINCIPAL INVESTIGATORS

Investigators on this project include: N. E. Weare, Metallurgist and Project Leader; E. Buchanan, Metallurgist; Dr. H. Marchandise, participating as EURATOM representative. Over-all supervision is exercised by Dr. D. R. Mash, Manager, Materials Department.

TABLE I

SUMMARY OF URANIUM DIOXIDE COATING DENSITIES
(Powder Type: Fused UO_2 , Traverse Rate: 71 ipm)

Powder Size (mesh)	Power Input (kw) ^a	Arc-Gas Flow Rate (cfm) ^b	Plasma Enthalpy (Kcal/ft ³) ^c	Powder-Gas Flow Rate (cfm) ^b	Powder Feed Rate (gm/min)	Spray Distance (in.)	Cover-Gas Flow Rate (cfm) ^b	Coating Density (% Theor.)	Remarks
-200, +325	25.1	1.25	260	0.14	29	4	None	86.7	
"	26.25	1.48	240	"	"	"	"	87.8, 89.1	
"	24	1.05	270	"	"	3	"	82.8, 85.5	Slight Spalling
"	25.5	1.25	265	"	"	"	"	86.6, 87.0	Spalling One Edge
"	21.0	0.78	"	"	54.5	4	"	75.6, 77.0	Slight Lifting
"	24.0	0.96	280	"	60	"	"	82.0	
"	25.5	1.24	265	"	"	"	"	87.1	Lifting
"	"	1.26	260	"	"	"	"	86.1, 88.7	
"	27.0	1.51	245	"	61	"	"	84.3, 86.6	
"	25.5	1.29	265	"	"	3	8	90.2	Slight Lifting
"	24.0	0.98	270	"	"	"	"	86.3, 86.6	"
"	25.5	1.29	265	"	"	"	"	81.5, 83.9	"
"	27.0	1.53	240	"	"	"	"	88.9, 89.5	"
"	24.0	0.98	280	"	"	2.5 ^d	"	83.1, 83.6	

a. Arc current: 750 amperes.

b. Argon.

c. Obtained from curves derived previously (Technical Progress Report dated September 1960, ATL-422; and D. R. Mash, N. E. Weare, and D. L. Walker, "Process Variables in Plasma Jet Spraying," presented at the AIME Technical Session, Plasma-Arc Applications to Metallurgy, 1961 Western Metals Congress, Los Angeles, California, March 23, 1961.

d. First pass at 2.5 inches; second at 3 inches; third through sixth at 3.75 inches.

TABLE I
(cont.)

Powder Size (mesh)	Power Input (kw) ^a	Arc-Gas Flow Rate (cfm) ^b	Plasma Enthalpy (Kcal/ft ³) ^c	Powder-Gas Flow Rate (cfm) ^b	Powder Feed Rate (gm/min)	Spray Distance (in.)	Cover-Gas Flow Rate (cfm) ^b	Coating Density (% Theor.)	Remarks
-200, +325	26.25	1.29	270	0.14	61	2.25 ^e	8	88.5	Slight Lifting
"	"	"	"	"	"	2.5 ^f	"	89.5, 89.5	
"	"	"	"	"	"	2.5 ^g	"	81.7, 87.9	
-270, +325	21	0.92	250	0.14	30	4	None	-	Poor Deposition
"	"	"	"	0.10	"	"	"	-	"
"	24.4	1.21	225	"	"	"	"	91.6	
"	23.25	"	250	0.14	"	"	"	82.9	
"	22.6	"	240	"	"	"	"	81.7	
"	24	1.24	250	0.10	"	"	"	83.9	
"	24.75	1.42	240	0.14	"	"	"	88.1	
"	"	1.44	"	"	"	"	"	84.1	
"	25.1	1.42	245	0.10	"	"	"	87.6	
"	24	1.24	250	"	60	"	"	75.7	
"	"	"	"	0.14	"	"	"	83.5	
"	"	1.23	"	"	"	"	"	85.1	
"	25.5	1.42	"	0.10	"	"	"	88.7	
"	"	"	"	0.14	"	"	"	85.1	

e. First pass at 2.25 inches; second and third at 3.5 inches.

f. First pass at 2.5 inches; second through sixth at 3 inches.

g. First pass at 2.5 inches; second through fifth at 3.25 inches; sixth through tenth at 4.25 inches.

TABLE I
(concl.)

Powder Size (mesh)	Power Input (kw) ^a	Arc-Gas Flow Rate (cfm) ^b	Plasma Enthalpy (Kcal/ft ³) ^c	Powder-Gas Flow Rate (cfm) ^b	Powder Feed Rate (gm/min)	Spray Distance (in.)	Cover-Gas Flow Rate (cfm) ^b	Coating Density (% Theor.)	Remarks
-270, +325	25.5	1.42	250	0.14	60	4	None	86.8	
"	24.75	1.26	260	0.10	"	3	8	87.1	
"	"	"	"	0.14	"	"	"	87.3	
"	25.1	1.47	240	"	"	"	"	87.1	
-325 (de- slimed)	26.25	1.26	270	"	58.7	"	~8	81.6, 81.6	
"	24.75	"	260	"	30	"	"	81.4	Lifted
"	26.25	1.73	220	"	43.8	"	"	82.8	
"	25.9	1.71	215	"	43.6	"	"	77.4	
"	27.0	1.98	170	"	44	"	"	85.4	

10

LEGEND	POWER INPUT (kw)	POWDER FEED (gm/min)
○	20.2-28.5	66
●	21.8-28.5	29
△	22.5-28.5	50
▲	21.0-28.5	16

POWDER SIZE: -200, +325 mesh
 ARC CURRENT: 750 amp
 SPRAY DISTANCE: 4 in.

EFFECT OF ARC-GAS FLOW ON RATE OF
 DEPOSITION OF UO_2 CONES
 (-200, +325 MESH FUSED UO_2 POWDER)

FIGURE 1

LEGEND	POWER INPUT	POWDER FEED	POWDER-GAS FLOW (ARGON) (cfm)
	(kw)	(gm/min)	(cfm)
○	24-27	30	0.14
●	20-25	30	0.10
△	24-25	60	0.14

POWDER SIZE: -325 mesh (de-slimed)
 ARC CURRENT: 750 amp
 SPRAY DISTANCE: 4 in.

EFFECT OF ARC-GAS FLOW ON RATE OF
 DEPOSITION OF UO_2 CONES
 (-325 MESH FUSED UO_2 POWDER)

FIGURE 2

LEGEND	POWDER SIZE	POWER INPUT	PLASMA ENTHALPY	SPRAY DISTANCE	POWDER FEED	COVER-GAS FLOW (ARGON) (cfm)
	(mesh)	(kw)	(Kcal/ft ³)	(in.)	(gm/min)	(cfm)
○	-200, +325	21-27	245-280	4	60	None
●	-270, +325	24-25.5	250	4	60	None
△	-325 (de-slimed)	26-27	170-220	3	44	8
+	-325 (de-slimed)	25-26	270	4	59	8

POWDER TYPE: Fused UO₂
 ARC CURRENT: 750 amp
 TRAVERSE RATE: 71 ipm
 POWDER-GAS FLOW (ARGON): 0.14 cfm

EFFECT OF ARC-GAS FLOW ON BULK DENSITY OF
 UO₂ COATINGS MADE FROM THREE POWDER SIZES

FIGURE 3

LEGEND	POWDER SIZE	POWER INPUT	SPRAY DISTANCE	POWDER-GAS FLOW (ARGON) (cfm)	COVER-GAS FLOW (ARGON) (cfm)
	(mesh)	(kw)	(in.)		
○	-200, +325	20	4	0.10	None
●	-200, +325	19-24	4	0.08	None
△	-270, +325	21-25	4	0.14	None
▲	-270, +325	20-25	4	0.08	None
□	-325 (de-slimed)	24-26	4	0.14	None
■	-325 (de-slimed)	25-26	3	0.14	8

POWDER FEED: 30 gm/min

EFFECT OF ARC-GAS FLOW ON DEPOSITION EFFICIENCY OF THREE SIZE RANGES OF FUSED UO_2 POWDER

FIGURE 4

POWDER SIZE: -200, +325 mesh
ARC-GAS FLOW (ARGON): 0.99 cfm
SPRAY DISTANCE: 4 in.
POWDER FEED: 30 gm/min
POWDER-GAS FLOW (ARGON): 0.085 cfm

EFFECT OF ELECTRICAL-POWER INPUT ON
DEPOSITION EFFICIENCY OF FUSED UO_2 POWDER

FIGURE 5

LEGEND	POWER INPUT	ARC CURRENT	POWDER FEED	POWDER-GAS FLOW (ARGON) (cfm)
	(kw)	(amp)	(gm/min)	(cfm)
○	21 -25.5	750	30	0.10
●	17.5-20.8	650	30	0.085
△	21 -25.5	750	60	0.10
□	19.4-23.9	750	30	0.085
+	20	600-750	30	0.10

POWDER SIZE: -200, +325 mesh
 SPRAY DISTANCE: 4 in.

EFFECT OF ARC-GAS FLOW RATE ON
 DEPOSITION EFFICIENCY OF FUSED UO_2 POWDER

FIGURE 6

POWDER SIZE: -200, +325 mesh
POWER INPUT: 20.2-23.2 kw
ARC-GAS FLOW (ARGON): 0.99 cfm
POWDER FEED: 30 gm/min
POWDER-GAS FLOW (ARGON): 0.085-0.10 cfm

EFFECT OF SPRAY DISTANCE ON
DEPOSITION EFFICIENCY OF FUSED UO_2 POWDER

FIGURE 7

CURVE	POWDER SIZE (mesh)	POWER INPUT (kw)	ARC-GAS FLOW (cfm)	PLASMA ENTHALPY (Kcal/ft ³)	POWDER FEED (gm/min)
A	-200, +325	22	0.99	255	30
B	-270, +325	25	1.25	260	60

SPRAY DISTANCE: 4 in.

EFFECT OF POWDER GAS FLOW ON
DEPOSITION EFFICIENCY OF FUSED UO_2 POWDER

FIGURE 8

DISTRIBUTION

	No. of Copies
Division of Reactor Development U. S. Atomic Energy Commission	
Attn: A. M. Labowitz, Assistant to the Director for Foreign Activities	5
Contracting Officer San Francisco Operations Office	
Attn: W. H. Brummett, Jr, Director Contracts Division	11
Contracting Officer San Francisco Operations Office	
Attn: G. F. Helfrich, Director Reactor Programs Division	1
Civilian Reactor Division U. S. Atomic Energy Commission Savannah River Operations Office	
Attn: Nathaniel Stetson, Director	1
Technical Information Service Extension Oak Ridge, Tennessee	3
ATL Files	33

STAT